DOCUMENT RESUME

ED 406 172 SE 059 836

AUTHOR Chang, Chun-Yen; Barufaldi, James P.
TITLE Initiating Change in Students' Achievement and Alternative Frameworks through a Problem Solving Based Instructional Model.
PUB DATE 22 Mar 97
NOTE 19p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (70th, Oak Brook, IL, March 22, 1997).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Academic Achievement; *Earth Science; Educational Strategies; Foreign Countries; High Schools; Misconceptions; Models; *Problem Solving; Questionnaires; *Student Attitudes; Teaching Methods
IDENTIFIERS Taiwan

ABSTRACT

The purpose of this study was to investigate the effects of a problem solving based instructional model on earth science students' achievement and alternative frameworks. Students' opinions toward the instructional method were also investigated. The investigations employed a pretest/posttest control group design to detect any significant change. The 172 participants enrolled in four earth science classes received six weeks of the problem-solving based instruction. Selected items from the Taiwan Entrance Examinations for Senior High School were used to measure achievement in Earth Science content. An instrument with open-ended questions was used to examine conceptual change while a 10-item Likert-type questionnaire was used to explore student opinions toward the instruction. Results of an analysis of covariance on achievement posttest scores revealed that the problem solving based instructional model did significantly improve the achievement of students, especially at the application level. A chi-square analysis on students' alternative frameworks measure indicated that students taught using the problem solving based instructional model experienced significant conceptual changes. Contains 33 references. (Author/JRH)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 406 172

Initiating Change in Students' Achievement and Alternative Frameworks Through a Problem Solving Based Instructional Model

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN OTHER THAN PAPER COPY HAS BEEN GRANTED BY
C.-Y. Chang
J. P. Barufaldi
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

Chun-Yen Chang
Department of Earth Sciences
National Taiwan Normal University, Taiwan, R.O.C.

James P. Barufaldi
Science Education Center
The University of Texas at Austin, Austin, Texas

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Abstract

The purpose of this study was to investigate the effects of a problem solving based instructional model on earth science students' achievement and alternative frameworks. In addition, students' opinions toward the problem solving based instructional method were also investigated. The investigations employed a pretest/posttest control group design to detect any significant change. The 172 participants enrolled in four earth science classes received six weeks of the problem-solving based instruction. Selected items from Taiwan Entrance Examinations for Senior High School were used to measure students' achievement in earth science content. An open-ended question instrument was developed by the researchers to examine students' conceptual change. A 10-item Likert-type questionnaire was administered to the participants of the experimental group to explore student opinions toward the problem solving based instruction. Results of an analysis of covariance on achievement posttest scores revealed that the problem solving based instructional model did significantly improve the achievement of students, especially at the application level. A chi-square analysis on students' alternative frameworks measure indicated that students taught using the problem solving based instructional model did experience significant conceptual changes than did students who were taught by the traditional-lecture type teaching method.

Problem solving and alternative frameworks have long gained much attention from researchers and science educators. The relationship between student achievement and their problem solving skills has been investigated by many researchers in the field of science education (Geban, Askar, & Ozkan, 1992; Saunders & Shepardson, 1987; Chiappetta & Russell, 1982; Russell & Chiappetta, 1981). Most of the research studies in problem solving have focused on physics, chemistry, and life science; yet, only a few studies have paid attention to earth science. As Aldridge (1993) stated, "Chemistry and physics are fundamental to an understanding of the life science. And chemistry, physics, and the life science are fundamental to an understanding of the Earth and space sciences." (p. 27). Since earth science is an integral part of the secondary science curriculum, and improving students' achievement has long been a primary goal of science education, it becomes important to investigate if a problem solving based instructional method will have positive effects on earth science students' achievement in seconcary schools.

BEST COPY AVAILABLE

While some previous research has shown that a problem solving teaching method can improve students' achievement (Russell & Chiappetta, 1981), few studies have tried to modify students' alternative frameworks through a problem solving based instruction. A number studies have investigated the use of teaching strategies to promote conceptual change among science students (Hewson and Hewson, 1983; Zietsman and Hewson, 1986; Smith, Blakeslee, and Anderson 1993). Very few studies have examined conceptual change associated with problem solving strategies. Studies on alternative frameworks are more plentiful in the area of physics, chemistry, biology than in earth science. Gil-Perez and Carrascosa (1990) proposed that conceptual change is not possible without a methodological change. These researchers suggested that a new methodology which integrates careful hypothesis checking, creative thinking and experiments, is the key to modify misconceptions or alternative frameworks of students. This new methodological change is, in essence, similar to the method of the problem solving strategies proposed in this study. Accordingly, it is necessary to investigate if problem solving based instruction can help students modify their alternative frameworks.

Purpose

The main purpose of this study is to investigate the effects of a problem solving based instructional model on the achievement and alternative frameworks of ninth grade earth science students in Taiwan. In addition, students' opinions toward the problem solving based instructional method are also investigated.

Method

Subjects

Students chosen to participate in the study included 172 ninth grade earth science students, age 14.5 years to 15.2 years, mean age at 14.8 years. These students enrolled in four earth science classes taught by the same teacher at a modern public junior high school located in the central region of Taiwan in the fall semester, 1995. Two intact classes (N=86) were randomly assigned to the experimental group and the other two sections (N=86) were randomly assigned to the control group. The earth science course, taught two hours per week for two consecutive semesters, is required of every ninth grade student in secondary schools in Taiwan.

The demographics of the subjects consist of 50% male students (N = 86) and 50% female students (N = 86). An IQ test of these students was administered earlier in the same semester. Fifteen percent of participating students are above average, 68% of students are average, and 17 % of the students are below average compared with the national level. The students were

typical of ninth grade students who had just started to receive formal earth science instruction three months before the investigations and were selected primarily for that reason.

Treatment

Selection of a problem solving model of instruction is one of the critical decisions the researchers made for the study. After reviewing models of problem solving based instructional method and much discussion with earth science teachers in Taiwan, the researchers determined that the Search, Solve, Create, and Share (SSCS) model developed by Pizzini, Abell, and Shepardson (1988) is the most appropriate model to infuse in secondary earth science classrooms because of the following: (1) "The SSCS model synthesized other problem solving models into fewer steps; thereby, simplifying the process for use with upper elementary and middle school students." (p. 526-527) stated by Pizzini, Shepardson, and Abell (1989); (2) The simple four steps would be easier for earth science students in Taiwan to learn and to get used to it since they have not been taught by this type of instructional method before; (3) The SSCS model embodies fundamental elements of conceptual change models.

The Search, Solve, Create, Share (SSCS) problem solving based instructional method was modified as the independent variable (treatment) in this study. The SSCS model is a four step cyclical model which involves searching, solving, creating and sharing, and allows for re-entry into various stages of the model during the problem solving process. Treatment consisted of a six-week period of earth science instruction based on the SSCS model. The earth science textbook copies for the six-week period include the following units: Unit Six - The Movement of the Earth Crust : Plate Tectonics (6 hours), Unit Seven - History of the Earth and Geologic Time (4 hours), and the first section of Unit Eight - The Ocean Current (2 hours). The following topics are introduced in these units: theory of continental drift, ocean-floor spreading, Plate Tectonics, earthquakes and scale of intensity, geologic features on the edge of Plates, stratigraphy, fossils and the past, change and geologic time, topography of the ocean, and ocean currents.

Students were taught units on the aforementioned topics by their classroom teacher based on the modified SSCS instructional approach, i.e., students' brainstorming and identifying problems were followed by preparing and implementing their plans by means of group discussions with an occasional student-designed activity, and class presentation of answers or ideas. Since ninth grade students in Taiwan have a heavy course load and take numerous tests, they do not have extra time to seek extra materials for themselves beyond the textbook. The Search phase of the SSCS model has been modified to have students' brainstorm and identify problems of researchable questions after reading articles from science newspapers or magazines and materials prepared by the researchers and the classroom teacher. It is noted that the very

same materials were also provided to the control group as a placebo control. The Solve phase was the same as the original model which required students to prepare and implement their plans by analyzing and investigating the researchable questions individually. The Create phase was adjusted so that students could generate a solution or solutions by group discussions and communications. The cooperative discussion groups sat at separate table and were asked to generate solutions and consensus on the solutions. During this stage students had the opportunity to discuss ideas and make their own concept more clear. Going beyond communications, students of a group reflected on, evaluated solutions and answers, and at times presented the ideas or answers to the class in the modified Share phase. At the conclusions of SSCS for each unit, the classroom teacher briefly summarized the content taught and led students to further questions. The most important characteristics of the lesson series are making students more skillful in problem solving strategies and helping pupils to become aware of their own ideas and others or even conflicting opinions in class to promote conceptual change. Both of the characteristics are also the goal and purpose of the instructional method.

Instruments

The following instruments were used in this study:

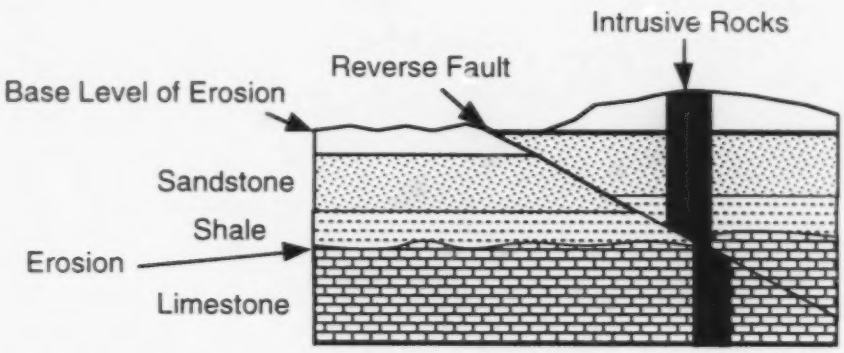
The Achievement Test. Student achievement was measured by the test, Taiwan Entrance Examination for Senior High School - earth science subject (TEESHS) and Taiwan Entrance Examination for Five-Year Junior College (TEEFYJC) - earth science subject. These tests are the most widely used achievement tests in Taiwan. The researchers and one earth science teacher compiled the test items selected from TEESHS and TEEFYJC from 1987 through 1995 based on the content of the earth science textbook used during the fall semester. Sixty-nine test items were selected and equally distributed from Unit one through Unit Five as the pretest. Pretest items are all relevant to textbook context prior to the investigations. Fifty-two items were selected for the posttest, which equally covers topics from Unit Six to the first section of Unit Eight. Posttest items are all specifically related to textbook content during the six-week treatment.

The content validity of the instruments was reviewed, approved, and verified by a panel of experts including one earth scientist, two earth science teachers of secondary schools. These experts checked the correspondence between textbook content and test items, and confirmed that the substance of the test items is coterminous to important concepts introduced in the textbook. Concurrent validity was calculated in a comparison with students' monthly examination scores and yielded 0.85 and 0.73 for the pretest and posttest respectively. The Kuder-Richardson Formula 21 (KR-21) and the split-half method were used to determine the reliability coefficient of the pretest and posttest. The reliability coefficient of 0.89 for the

pretest and 0.89 for the posttest (KR-21) were noted. Split-half reliability yielded 0.92 and 0.90 for the pretest and posttest respectively.

The following is an example of the questions used in the posttest:

Which one of the following descriptions is inaccurate based upon the stratigraphic cross section shown below? (1) deposition, erosion, intrusions, and faulting occurred before (2) Because of tremendous heat, the rocks surrounding the intrusive rocks might form a ore deposit through metamorphism (3) reverse fault is the most recent geological process (4) one can only judge the relative age rather than the absolute age of these geological processes based upon this diagram.



(Adapted from the Taiwan Provincial TEESHS, 1993)

Both pretest and posttest items were also classified into two categories (knowledge and application) based on Bloom's Taxonomy (1956). It is noted that analysis, synthesis, and evaluation were not considered as appropriate levels by the researchers for the ninth grade student on the tests. Because ninth grade students just started developing formal operational ability and the nature of TEESHS tests only aligns with knowledge and application level items. A panel of one science educator and two secondary school earth science teachers, who were knowledgeable about Bloom's Taxonomy, classified these items into the categories with high correlation and few disagreements were resolved after discussion. As a result, the pretest included thirty-seven items at the knowledge level and thirty-two items at the application level. The posttest consisted of seventeen knowledge level items and thirty-five items of application level.

The reliability coefficients for the knowledge level items of pretest were 0.60 (KR-21) and 0.85 (split-half method). Application level items of pretest produced reliability coefficients of 0.57 (KR-21) and 0.83 (split-half method). The reliability coefficients of the posttest subscales for the knowledge (KR-21), knowledge (split-half method), application (KR-21), and application level (split-half method) were 0.49, 0.84, 0.74, 0.88 respectively.

AFS INSTRUMENT. Students' alternative frameworks were determined by the AFS INSTRUMENT developed by the researchers. The study employed an open-ended essay-question-type instrument to measure students' conceptual changes. Questions in the instrument were open-ended to encourage pupils to express their opinions thoroughly. In order to prevent pretest sensitization, three open-ended questions were included in the instrument, and only the following question targeted the alternative framework in this study. The target question follows: "What do you think causes mountains to form? Please try to express everything you know about this question. A sketch or picture sometimes will help you to explain the phenomenon". The instrument was evaluated on a category scale and analyzed to determine levels of students' understanding for different phenomena in earth science. The three open-ended questions were determined as open-ended and appropriate for secondary students by one university professor and two earth science teachers in secondary schools in Taiwan.

The categorization system used by Simpson and Marek (1988) was adapted to classify responses as following: (1) An Understanding (U) - students are able to clarify their understanding of science concept which is also consistent with the established scientific views, (2) Partial Understanding (PU) - students have acquired some understandings of science concept even although these ideas are not in an integrated or unified way, (3) clearly evident Alternative Framework (AF) - students give just one simplistic, incongruent viewpoint different from those of scientists, (4) Confused, Faulty outcomes (CF) - students' explanations of natural phenomenon are confused and contradictory to each other, and (5) No conception (NC) - students do not have answers or ideas about the phenomenon.

The following modified criteria developed by Muthukrishna, Carnine, Grossen, and Miller (1993) were used to categorize answers on the aforementioned AFS INSTRUMENT: (p. 239).

1. An Understanding (U): The answer includes two or more of the following ideas: (a) convection in the mantle causing the movement of earth's tectonic plates, (b) tectonic plates of earth getting pushed together at subduction zone or pulled apart at mid-ocean ridges, (c) two tectonic plates coming together causing volcanoes, and mountains, or pulling apart resulting in mid-ocean ridges.

2. Partial Understanding (PU): The answer includes at least one of the aforementioned ideas or concepts in the Understanding (U) category.

3. Clearly evident AFs (AF): An answer that is clearly incongruent with the accepted scientific theories, such as : (a) movement of faults, (b) sand pilling up and becoming mountains, (c) mountains growing, (d) winds, weather, and erosion (e) magma piling up (f) earthquakes (g) retreat of ocean.

4. Confused, faulty understanding (CF): The answer includes at least one idea from both categories 2 and 3 above.

5. No conception (NC): Students declined to answer.

Students' response were then evaluated and scored independently and blindly by the researcher and another earth science teacher in terms of numbers of categorizing answers based on the aforementioned criteria. Interrater reliability and correspondence (Pearson Product-Moment Correlation Coefficient) was computed as 0.93 and few disagreements were resolved by discussions between the raters after completing the scoring procedure.

Student Opinions Questionnaire. To analyze the experimental group students' perceptions toward the problem solving based instructional model in the secondary science classrooms, a Likert-type questionnaire, Student Opinions Questionnaire with a 5-item semantic differential scale was administered to elicit students' opinions on the specific teaching-learning approach. Opinions were differentiated on a scale that ranged form 1 - "strongly agree" or "strongly like" to 5- "strongly disagree" or "strongly dislike." A total of nine question items and one student comment section dealing with the problem solving based instructional model were included in the questionnaire. Likert-type questions and students' statements on the comment section aimed at exploring student affective perceptions toward the problem solving based instructional method.

Procedures

A pilot study was first conducted in the fall semester, 1994 one year before the main study was carried out in the same secondary school in Taiwan. The main purpose of this pilot study was (1) to train the teacher who participated in the main study to enable the teacher to become familiar with the problem solving based instructional method; (2) to delineate the demographic characteristics of ninth grade students in the school. The design of the main study employed a quasi-experimental pretest/posttest control group design to carry out the investigations.

An analysis of covariance was used to determine the differences between the experimental group and the control group on post-treatment achievement of posttest with pretest and students' IQ as covariates. A more detailed analysis of covariance was also conducted at the knowledge and the application level of the posttest measures to determine if there were significant differences between the two groups at the aforementioned levels. A chi-square analysis was also conducted to determine if there existed significant differences between students' pretest and posttest responses on the alternative frameworks measure by classes and groups (the experimental and control group). The research design and procedures are summarized in Figure 1.

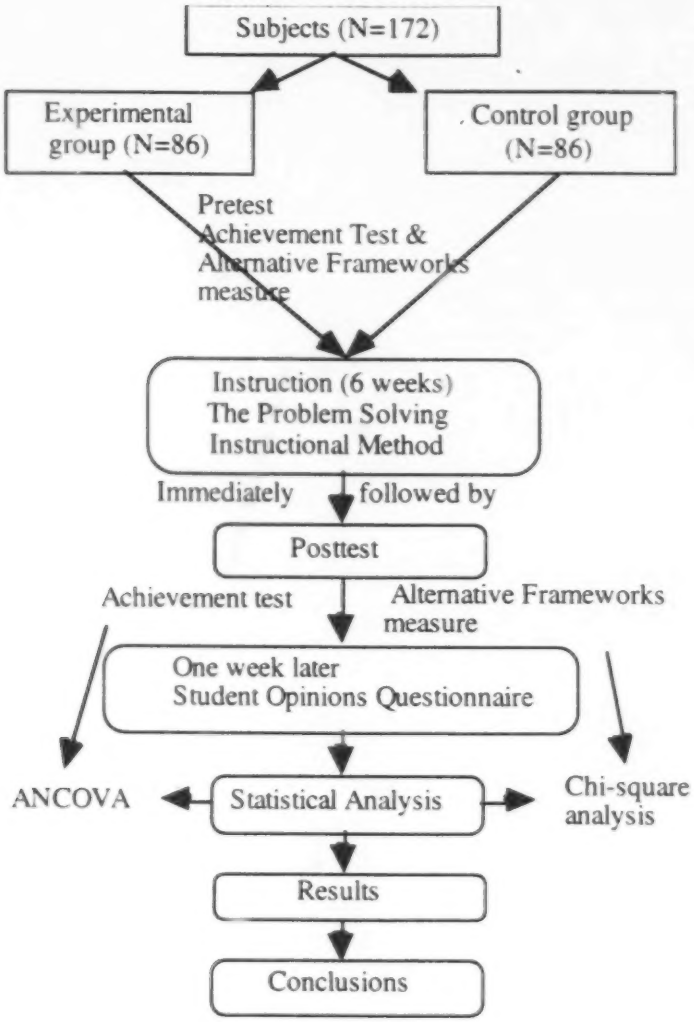


Figure 1. Summary of Research Design and Procedures.

Results

An analysis of covariance (ANCOVA) was conducted to detect if significant difference existing between students' posttest performance. The scores on the pretest and IQ were used as covariates. The assumptions of ANCOVA were first checked to be met in the analysis of covariance for the study. The results of ANCOVA are summarized in Table 1, 2, and 3. As shown in these tables, The results of achievement investigation revealed that the problem solving based instructional method produced significantly greater achievement of ninth grade earth science students than the conventional teaching method ($F = 4.10$, $p < 0.04$ in Table 1), especially at the application level ($F = 4.56$, $p < 0.03$ in Table 3).

ANCOVA					
Source of Variation	*SS*	*df*	*MS*	*F*	*F Prob.*
Covariates	9086.09	2	4543.04	110.80	
Between Groups	168.27	1	168.27	4.10*	0.044
Within Groups	6806.50	166	41.00		
Total	16018.00	169			

	Covariates		Posttest	
Groups	Pretest means	IQ means	unadjusted means	adjusted means
Experimental	45.612	50.012	29.859	29.996
Control	45.776	51.518	28.141	28.004

Table 1. Summary of Analysis of Covariance on Students' Posttest Scores

ANCOVA					
Source of Variation	*SS*	*df*	*MS*	*F*	*F Prob.*
Covariates	1248.23	2	624.12	74.51	
Between Groups	5.47	1	5.47	0.65	0.42
Within Groups	1390.40	166	8.38		
Total	2639.11	169			

	Covariates		Posttest	
Groups	Pretest means	IQ means	unadjusted means	adjusted means
Experimental	24.294	50.012	10.412	10.538
Control	24.800	51.518	10.306	10.179

Table 2. Summary of Analysis of Covariance for the Knowledge Level Items on Students' Posttest Scores

ANCOVA					
Source of Variation	*SS*	*df*	*MS*	*F*	*F Prob.*
Covariates	3237.54	2	1618.77	70.03	
Between Groups	105.42	1	105.42	4.56*	0.034
Within Groups	3837.16	166	23.12		
Total	7185.11	169			

	Covariates		Posttest	
Groups	Pretest means	IQ means	unadjusted means	adjusted means
Experimental	21.318	50.012	19.447	19.431
Control	20.976	51.518	17.835	17.851

Table 3. Summary of Analysis of Covariance for the Application Level Items on Students' Posttest Scores.

Group	Level of under-standing	Experimental Number of responses (%)	Control Number of responses (%)	χ^2	p
Pretest	U	1 (1%)	1 (1%)	5.86	<0.25
	PU	7 (8%)	2 (2%)		
	AF	60 (70%)	71 (83%)		
	CF	4 (5%)	1 (1%)		
	NC	14 (16%)	11 (13%)		
Posttest	U	18 (21%)	3 (3%)	21.63	<0.001
	PU	26 (30%)	16 (19%)		
	AF	12 (14%)	26 (30%)		
	CF	6 (7%)	14 (16%)		
	NC	24 (28%)	27 (31%)		

Table 4. Chi-Square Analysis on Students' AFS INSTRUMENT Responses Comparing Between the Experimental and the Control Group Differences on the Pretest and the Posttest

It is also statistically supported that students taught by the problem solving based instructional model did experience a significant conceptual change than students who were taught by the traditional-lecture type teaching method ($\chi^2 = 21.63$, $p<0.001$ in) as shown in Table 4, even though both instructional methods were successful in modifying students' alternative frameworks ($\chi^2 = 61.18$, $p<0.001$ for the experimental group and $\chi^2 = 50.77$, $p<0.001$ for the control group from Table 5, respectively).

Group	Level of under-standing	Pretest Number of responses (%)	Posttest Number of responses (%)	χ^2	p
Experimental Group	U	1 (1%)	18 (21%)	61.18	<0.001
	PU	7 (8%)	26 (30%)		
	AF	60 (70%)	12 (14%)		
	CF	4 (5%)	6 (7%)		
	NC	14 (16%)	24 (28%)		
Control Group	U	1 (1%)	3 (3%)	50.77	<0.001
	PU	2 (2%)	16 (19%)		
	AF	71 (83%)	26 (30%)		
	CF	1 (1%)	14 (16%)		
	NC	11 (13%)	27 (31%)		

Table 5. Chi-Square Analysis on Students' AFS INSTRUMENT Responses Comparing the Pretest and the Posttest Changes by the Categories of Understanding

Results of student opinions toward the problem solving based instructional method suggest that students in the experimental group demonstrated no particular perceptions toward this teaching approach, yet, they all expressed the advantages of the problem solving instructional model in terms of helping them develop analytical and observing skills, and improving their thinking skills. The results also reveal that students did not believe that the problem solving based instructional method would have positive effects on their forthcoming achievement in earth science, although students in the treatment group outperformed those students enrolled in the conventional class. Students did believe, however, that the instructional model helped develop their thinking skills and enhanced their scientific abilities.

Discussions

The results of achievement investigation can be concluded with high degree of confidence that the problem solving based instruction did significantly improve ninth grade earth science

students' achievement ($F = 4.10$, $p < 0.04$). The results of this investigation support previous work (Russell & Chiappetta, 1981; Saunders & Shepardson, 1987; Geban, Asker, & Ozkan, 1992), in which those studies demonstrated positive effects of a problem solving instructional model on students' science achievement. The greatly improved achievement of earth science students as a result of treatment renders the following conclusions:

1. The success of the problem solving based instructional model primarily resulted from the emphasis of the instruction on problem solving strategy, logical thinking skills and other process skills of students because pupils receiving the treatment were provided the opportunity to observe, hypothesize, record, predict, think, analyze and conclude on their own. Accordingly, these scientific or process skills might help students ways that the differences of students' learning earth science were thus reflected on the achievement performance between the treatment and control group.

2. The nature of the posttest items is generally aligned with the fundamental elements of the problem solving based instructional model because there are 67% of application level items in the posttest. The TEESHS or TEEFYJC test items often require of students' higher mental ability or problem solving skills for them to perform better on the test. Therefore, students in the experimental group may outperform students in the control group on the posttest as a result of enhancement of these required process skills.

3. Since there were significant differences at the application level but not at the knowledge level between students in two groups, the emphasis of the problem solving based model on application, problem solving skills and thinking skills might have been the major factor contributing to the overall increase in earth science achievement among students in the treatment group.

These conclusions become more explicit when one carefully examines the results of the investigations in the analysis of the sublevel posttest items - the knowledge and the application level of Bloom's Taxonomy. The result of the investigation at the knowledge level showed no significant differences in the achievement of students between the experimental group and the control group ($F = 0.65$, $p < 0.42$). Since rote memorization and learning might assist students' performance at the knowledge level, it is reasonable to infer that students receiving the problem solving instructional method did not necessarily perform better than students taught by the conventional approach. The results of data analyses at the knowledge level support this viewpoint. Conversely, students receiving the problem solving based instructional method did perform significantly better on achievement at the application level than those students who were taught using the conventional approach ($F = 4.56$, $p < 0.03$), which apparently resulted from the application emphasis of the problem solving based instructional model.

The above result is also consistent with results from other studies in this area, which reported that a problem solving approach did improve science achievement of pupils especially at higher cognitive levels of Bloom's Taxonomy (Henkel, 1968; Gabel, Rubba, & Franz, 1977; Chiappetta & Russell, 1982; Saunders & Shepardson, 1987; Mulopo & Fowler, 1987; Geban, Askar, & Ozkan, 1992). Students in the experimental group were provided with opportunities to search and collect information, formulate hypothesis, interpret phenomenon, analyze data, infer results, draw conclusions, and share or communicate ideas. These procedures encouraged students to take an active role in the learning process which in turn led to the superiority of the problem solving instruction to the traditional teaching method at the application level. This result supports the learning hierarchy model proposed by Gagne (1965), who classified problem solving as higher order of learning which also corresponds to the application level thinking described by Bloom (1956).

The results of alternative frameworks investigation indicate that both instructional methods were significantly effective in modifying students' alternative frameworks, χ^2 = 61.18, $p<0.001$ for the experimental group and χ^2 = 50.77, $p<0.001$ for the control group. Students discussed about the content, the form of mountains, in the treatment group. This topic was also addressed by the teacher in the control group during class period. Therefore, it is reasonable to infer that both instructional methods were effective in inducing pupils' conceptual change. The result also reveals that students taught using the problem solving instructional method changed their alternative frameworks to a greater degree than those enrolled in the traditional classes (χ^2 = 21.63, $p<0.001$). The following reasons support the difference in conceptual change between the experimental group and the control group:

1. The cooperative group discussions may have provided students the opportunity to confront their existing non scientific views and search for a more fruitful and intelligent one to interpret phenomenon. Because in a small group discussion environment students can feel free to share ideas without confronting "fear of stupidity or ridicule". This conclusion is consistent with Lonning's (1993) statement that cooperative learning strategies enhance conceptual change instruction and supports the conclusions of Thorley and Treagust (1987), that interpersonal conflicts and interactions can stimulate pupils' conceptual change.

2. The application of the science concept stressed by the problem solving model requires students' full understanding of earth science content and application of a new-learned concept to different situations, which may initiate conceptual change. This rationale upholds Brumby's (1984) conclusions that lectures are not sufficient to stimulate in confronting students' existing naive conception and to modify their alternative frameworks. Therefore, solving problems and applying concepts to real world situations are the keys to induce conceptual changes.

3. The key elements of the problem solving based instructional model which are aligned with the essence of a constructivist approach may have produced the significant differences between the two groups. As Thijs (1992) states: "The teaching approach shows its constructivist character by starting from students' prior ideas, and by promoting conceptual change through practical experiments and classroom discussions" (p.156). Students searched information and formulated hypothesis based on their prior knowledge during the Search phase. They then collected and analyzed data, and discussed and interpreted results at the Solve and Create stages. Students finally created and prepared their presentations in the Share phase of the SSCS model. Through these important processes or stages in the model, students were given many opportunities to change their alternative frameworks into a more plausible and compatible one.

Nevertheless some students' AFs about the "form of mountains" are resistant to change as shown in Table 4 and 5; 21% of students in the experimental group and 46% of pupils in the control group held AFs even after being taught by both formal earth science instructional methods. This result to some extent supports other studies in this area of alternative frameworks (Viennot, 1979; McCloskey, Caramazza, & Green, 1980; Clement, 1982; Champagne, Klopfer, & Gunstone, 1982; Halloun & Hestenes, 1985; Driver & Oldham, 1986), which concluded that students' AFs are difficult to change via instruction. As discussed above, group discussions may be useful in inducing students' conceptual change; yet, these discussions may have opposite or deleterious effects when students with alternative frameworks try to persuade other students into believing a particular alternative framework. The observation of students in the same group possessing similar AFs during class presentation might help explain students' retention of alternative frameworks after treatment.

What are the primary alternative frameworks in the subject area of the "form of mountain"? Happs (1982) reported that mountains are viewed by secondary students as "a large hill" or "big rocky structure" and children often associated the ""form of mountains" with "wind deposition", "underground pressure", or "God built it". This perception of students is similar to the result of the study. In this study, students' alternative frameworks regarding the "form of mountains" included a variety of ideas such as mountains growing, erosion by the rivers or glaciers, or weathering by the wind and subsequent to deposition or piling up of sedimentary rocks or soil, movement of faults, folding of formation rocks, accumulations of magma from volcanoes activity, mountains show up after regression of sea, and earthquakes. In the pretest, students primarily associated the "form of mountain" with mountains growing and erosion and deposition by different geologic forces or processes before formal earth science instruction. These students had just recently learned these concepts from previous units

in the semester and tried to apply them to the new situation or problem (the form of mountains). As Shuell (1986) noted "These errors....., they represent what students reasonably consider to be appropriate ways of dealing with the problem on which they are working, given their current knowledge (i.e., prior knowledge)." (p.430). It is apparent that prior knowledge plays an important role in students' subsequent learning.

The results of the two investigations above are reflected in the theory of John Anderson's ACT (1982, 1983). The problem solving model in the study proposed science learning as a methodological change (problem solving process) and conceptual change, emphasizing that science teaching should not only be centered on the declarative knowledge (knowing "what") (corresponding to the knowledge level) but also focus on the procedural knowledge (knowing "how") (corresponding to the application level). "Knowing what" enables students to recite the knowledge but not use it; "knowing how", on the other hand, allows students to apply knowledge and concepts to new situations. The problem solving based instructional model implemented in the study places the emphasis more on the latter than the former to facilitate learning, therefore contributing to the greater achievement at the application level and eminent modification of students' alternative frameworks. In fact, the nature of methodological and conceptual change can facilitate students' learning procedural knowledge which is inferred from the facts available in the declarative knowledge system.

Educational Implications

The present study, along with previous studies, show that a model of problem solving based instruction significantly increases students' science achievement and notably modifies alternative frameworks of students. This approach with an emphasis on application of science concepts, develops students' higher mental skills and facilitates students' learning of earth science. These findings support the notion that teachers need to encourage students to develop their process skills as early as possible in the educational system in order to promote science learning in the classroom.

Integrating models of problem solving and conceptual change instruction and putting them into science classroom practice have been determined to be fruitful and beneficial in developing students' scientific process skills, promoting their science achievement, and inducing pupils' conceptual change as a result of this study. Students' active searching for information and participating in cooperative group discussions are considered productive in the learning process for acquiring knowledge and understanding concepts in earth science.

Group discussions and cooperative learning are important stages within the problem solving based instruction and contribute to the significant learning outcomes of students in the experimental group. As proposed by Champagne, Gunstone, and Klopfer (1985), group

discussions and sharing ideas with others are very important in modifying students' alternative frameworks.

Science teaching should encourages students' own meaningful learning and process skills. This clearly implies that application of science concepts rather than rote learning or memorization should be emphasized and stressed in the science classroom to help students develop higher level thinking skills. Teachers should also identify the prior knowledge or concepts that students possess before instruction which might facilitate students' learning of science concepts and promote conceptual change. In addition, teachers need to explicitly address the difficulties that students may encounter when pupils apply new-learned concept to real-world problems.

It is apparent that prior knowledge plays an important role in science teaching and learning based on the analysis of students' AFs in the study. It is suggested that learning should involve personal restructuring ideas rather than merely assimilation of concepts. It is believed by the researchers that effective instruction such as the problem solving based instruction should build upon students' prior knowledge and lead students to construct their own meaningful learning through searching, participating in group discussions, and communicating ideas.

References

Aldridge, B. G. (1993). Basic components of the natural sciences. In National Science Teachers Association, Scope, sequence, and coordination of secondary school sciences: Volume I-the content core, pp. 25-40. Washington, D. C.: Author.

Anderson, J. R. (1982). Acquisition of cognitive skill. Psychological Review, 89, 369-406.

Anderson, J. R. (1983). The Architecture of Cognition. MA: Harvard University Press.

Bloom, B. S. (1956). (Ed.), Taxonomy of Educational Objectives. Handbook I: Cognitive Domain. New York: David McKay.

Brumby, M. N. (1984). Misconceptions about the concept of natural selection by medical biology students. Science Education, 68(4), 493-503.

Champagne, A. B., Gunstone, R. F. & Klopfer, L. E. (1985). Effecting changes in cognitive structures among physics students. In L. H. T. West & L. Pines (Eds.). Cognitive structure and conceptual change. Orlando, FL: Academic Press.

Champagne, A. B., Klopfer, L. E., & Gunstone, R. F. (1982). Cognitive research and the design of science instruction. Educational Psychologist, 17, 31-35.

Chiappetta, E. L., & Russell, J. M. (1982). The relationship among logical thinking, problem solving instruction, and knowledge and application of earth science subject matter. Science Education, 66(1), 85-93.

Clement, J. (1982). Students preconceptions in introductory mechanics. American Journal of Physics, 50(1), 66-71.

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105-122.

Gabel, D. L., Rubba, P. A., & Franz, J. R. (1977). The effect of early teaching and training experience on physics achievement, attitudes toward science and science teaching, and process skill proficiency. Science Education, 61(4), 503-511.

Gagne, R. M. (1965). The Conditions of Learning. New York: Holt, Rinehart and Winston.

Geban, O., Askar, P., & Ozkan, I. (1992). Effects of computer simulations and problem-solving approaches on high school students. Journal of Educational Research, 86(1), 5-10.

Gil-Perez D., & Carrascosa J. (1990). What to do about science "misconceptiόns". Science Education, 74(5), 531-540.

Halloun, I. A. & Hestenes, D. (1985). The initial knowledge state of college physics students. American Journal of Physics, 53, 1043-1055.

Happs, J. C. (1982). Mountains, LISP working paper 202, Science Education Research Unit, University of Waikato, Hamilton, New Zealand.

Henkel, E. T. (1968). Undergraduate physics instruction and critical thinking ability. Journal of Research in Science Teaching, 5, 89-95.

Hewson, M. G., & Hewson, P. W. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. Journal of Research in Science Teaching, 20(8), 731-743.

Lonning R. (1993). Effect of cooperative learning strategies on student verbal interactions and achievement during conceptual change instruction in 10th grade general science. Journal of Research in Science Teaching, 30(9), 1087-1101.

McCloskey, M., Caramazza, A., & Green, B. (1980). Curvilinear motion in the absence of external forces: Naive beliefs about the motion of objects. Science, 210, 1139-1141.

Mulopo, M. M., & Fowler, H. S. (1987). Effects of traditional and discovery instruction approaches on learning outcomes for learners of different intellectual development. A study of chemistry students in Zambia. Journal of Research in Science Teaching, 24(3), 217-227.

Muthukrishna, N., Carnine, D., Grossen, B., and Miller, S. (1993). Children's alternative frameworks: Should they be directly addressed in science instruction? Journal of Research in Science Teaching, 30(3), 233-248.

Pizzini, E. L., Abell, S. K., & Shepardson, D. P. (1988). Rethinking thinking in the Science

classroom. The Science Teacher, 55, 22-25.

Pizzini, E. L., Shepardson, D. P., & Abell, S. K. (1989). A rationale for and the development of a problem solving model of instruction in science education. Science-Education, 73(5), 523-534.

Russell, J. M., & Chiappetta, E. L. (1981). The effects of a problem solving strategy on the achievement of earth science students. Journal of Research in Science Teaching, 18(4), 295-301.

Saunders, W., & Shepardson, D. P. (1987). A comparison of concrete and formal science instruction upon science achievement and reasoning ability of sixth grade students. Journal of Research in Science Teaching, 24(1), 39-51.

Shuell, T. J. (1986). Cognitive conceptions of learning. Review of Educational Research, 56(4), 411-436.

Simpson, W. D., & Marek, E. A. (1988). Understandings and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. Journal of Research in Science Teaching, 25(5), 261-374.

Smith, E. L., Blakeslee, T. D., & Anderson, C. W. (1993). Teaching strategies associated with conceptual change learning. Journal of Research in Science Teaching, 30(2), 111-126.

Thijs, G. D. (1992). Evaluation of an introductory course on "Force" considering students' preconceptions. Science-Education, 76(2), 155-174.

Thorley, N. R., & Treagust, D. F. (1987). Conflict within dyadic interactions as a stimulant for conceptual change in physics. International Journal of Science Education, 9(2), 203-216.

Viennot, L. (1979). Spontaneous reasoning in elementary dynamics. European Journal of Science Education, 1, 205-221.

Zietsman, A. I., & Hewson, P. W. (1986). Effect of instruction using microcomputer simulations and conceptual change strategies on science learning. Journal of Research in Science Teaching, 23(1), 27-39.